Electronic Version

Stylesheet Version v1.1.1

Claims

[c1] What is claimed is:

1. A method for fast monitoring the stress-induced degradation of an insulation layer in a capacitor by a wafer acceptance testing (WAT) equipment, the method comprising:

(a) providing a substrate, a surface of the substrate comprising a first conductive layer, a second conductive layer, and the insulation layer disposed between the first conductive layer and the second conductive layer;

(b) applying a first voltage to the first conductive layer, the first voltage being a swing time-dependent DC ramping voltage;

(c) measuring a first leakage current flowing through the first conductive layer to calculate a first proportional value from the first voltage, the first leakage current, and an equation, the first proportional value corresponding to the first voltage;

(d) applying a second voltage to the first conductive layer, the second voltage being a swing time-dependent DC ramping voltage;

(e) measuring a second leakage current flowing through the first conductive layer to calculate a second propor-

tional value from the second voltage, the second leakage current, and the equation, the second proportional value corresponding to the second voltage; and

(f) calculating a first ratio of the second proportional value to the first proportional value.

[c2] 2. The method of claim 1 wherein the substrate is a silicon substrate of a semiconductor wafer.

[c3] 3. The method of claim 2 wherein the first conductive layer is a top electrode plate of the capacitor, the second conductive layer is a bottom electrode plate of the capacitor, and the capacitor is formed in a testing area of the semiconductor wafer.

[c4] 4. The method of claim 2 wherein the first conductive layer is a bottom electrode plate of the capacitor, the second conductive layer is a top electrode plate of the capacitor, and the capacitor is formed in a testing area of the semiconductor wafer.

[c5] 5. The method of claim 1 wherein the material composition of both the first conductive layer and the second conductive layer comprise metal, polysilicon, or other conductive materials.

[c6] 6. The method of claim 1 wherein the material composition of the insulation layer comprises silicon oxide, sili-

con nitride, or silicon oxynitride.

[c7] 7. The method of claim 1 wherein the insulation layer is an oxygen-contained thin film, and a weight percent of oxygen in the oxygen-contained thin film is smaller than 60%.

[c8] 8. The method of claim 1 wherein the insulation layer is a low-k material layer, and the material composition of the low-k material layer comprises at least two elements selected from a group consisting Si, C, H, O, N, and F, where a weight percent of oxygen in the low-k material layer is between 0 and 60%.

[c9] 9. The method of claim 1 further comprising a comparing step to compare the value of the first ratio with a predetermined value.

[c10] 10. The method of claim 9 wherein the quality of the insulation layer is degenerated to be not acceptable when the value of the first ratio is greater than the predetermined value.

[c11] 11. The method of claim 1 wherein the equation is the Fowler-Nordheim tunneling mechanism equation.

[c12] 12. The method of claim 9 wherein each proportional value is a β value corresponding to each voltage respec-

tively.

[c13] 13. The method of claim 12 wherein the first proportional value is a β1 value corresponding to the first voltage and the β1 value is equal to

【{△ln[|the first leakage current|/(|the first voltage|-|a flat band voltage(V_{fb})|)^2]}÷{△[1 ÷(|the first voltage|-|the flatband voltage|)]}】

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[c14] 14. The method of claim 12 wherein the second proportional value is a β2 value corresponding to the second voltage and the β2 value is equal to

【{△ln[|the second leakage current|/(|the second voltage|-|the flatband voltage(V_{fb})|)^2]}÷{△[1÷(|the second voltage|-|the flatband voltage|)]}】

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[c15] 15. The method of claim 12 further comprising the following steps when the value of the first ratio is not greater than the predetermined value:
applying a third voltage to the first conductive layer, the third voltage is a swing time-dependent DC ramping voltage;
measuring a third leakage current flowing through the first conductive layer;
calculating a third proportional value from the third volt-

age, the third leakage current, and the equation, the third proportional value corresponding to the third voltage;

calculating a second ratio of the third proportional value to the second proportional value; and

performing the comparing step to compare the value of the second ratio with the predetermined value.

[c16] 16. The method of claim 15 wherein the steps (b) to (f) are repeated when the value of the second ratio is not greater than the predetermined value.

[c17] 17. The method of claim 15 wherein the quality of the insulation layer is degenerated to be not acceptable when the value of the second ratio is greater than the predetermined value.

[c18] 18. The method of claim 15 wherein the third proportional value is a β3 value corresponding to the third voltage and the β3 value is equal to

【{△ln[|the third leakage current|/(|the third voltage|-|a flatband voltage(V_{fb})|)^2]}÷{△[1÷(|the third voltage|-|the flatband voltage|)]}】

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[c19] 19. The method of claim 18 further comprising a step for plotting a β-V curve of each β value respectively corre-

sponding to the first voltage, the second voltage and the third voltage versus the first voltage, the second voltage and the third voltage, a reference β-V curve for the un-stress-induced insulation layer is compared with the β-V curve to monitor the quality of the insulation layer.

[c20] 20. The method of claim 19 wherein the β-V curve comprises at least two regions.

[c21] 21. The method of claim 19 wherein the absolute value of the β value increases to represent the stress-induced leakage current (SILC) resulting in the increase of each leakage current flowing through the first conductive layer.

[c22] 22. The method of claim 12 further comprising a step for plotting a β-V curve of each β value versus each voltage, a reference β-V curve for the unstress-induced insulation layer in the capacitor is compared with the β-V curve to monitor the quality of the insulation layer.

[c23] 23. A method for fast monitoring the stress-induced degradation of an inter layer dielectric disposed between an upper layer interconnection line and a lower layer interconnection line by a wafer acceptance testing (WAT) equipment, the method comprising:

(a) applying a first voltage to the upper layer intercon-

nection line, the first voltage being a swing time-dependent DC ramping voltage;

(b) measuring a first leakage current flowing through the upper layer interconnection line to calculate a first proportional value from the first voltage, the first leakage current, and an equation, the first proportional value corresponding to the first voltage;

(c) applying a second voltage to the upper layer interconnection line, the second voltage being a swing time-dependent DC ramping voltage;

(d) measuring a second leakage current flowing through the upper layer interconnection line to calculate a second proportional value from the second voltage, the second leakage current, and the equation, the second proportional value corresponding to the second voltage; and

(e) calculating a first ratio of the second proportional value to the first proportional value.

[c24] 24. The method of claim 23 wherein the substrate is a silicon substrate of a semiconductor wafer, and the interconnection structure is formed in a testing area of the semiconductor wafer.

[c25] 25. The method of claim 23 wherein the material composition of both the upper layer interconnection line and the lower layer interconnection line comprise aluminum, copper, or other conductive materials.

[c26] 26. The method of claim 23 wherein the material composition of the inter layer dielectric comprises silicon oxide, silicon nitride, or silicon oxynitride.

[c27] 27. The method of claim 23 wherein the inter layer dielectric is an oxygen-contained thin film, and a weight percent of oxygen in the oxygen-contained thin film is smaller than 60%.

[c28] 28. The method of claim 23 wherein the inter layer dielectric is a low-k material layer, and the material composition of the low-k material layer comprises at least two elements selected from a group consisting Si, C, H, O, N, and F, where a weight percent of oxygen in the low-k material layer is between 0 and 60%.

[c29] 29. The method of claim 23 further comprising a comparing step to compare the value of the first ratio with a predetermined value.

[c30] 30. The method of claim 29 wherein the quality of the inter layer dielectric is degenerated to be not acceptable when the value of the first ratio is greater than the predetermined value.

[c31] 31. The method of claim 23 wherein the equation is the Fowler-Nordheim tunneling mechanism equation.

[c32] 32. The method of claim 29 wherein each proportional value is a β value corresponding to each voltage respectively.

[c33] 33. The method of claim 32 wherein the first proportional value is a β1 value corresponding to the first voltage and the β1 value is equal to

【{△ln[|the first leakage current|/(|the first voltage|-|a flat band voltage(V_{fb})|)^2]}÷{△[1 ÷(|the first voltage|-|the flatband voltage|)]}】

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[c34] 34. The method of claim 32 wherein the second proportional value is a β2 value corresponding to the second voltage and the β2 value is equal to

【{△ln[|the second leakage current|/(|the second voltage|-|the flatband voltage(V_{fb})|)^2]}÷{△[1÷(|the second voltage|-|the flatband voltage|)]}】

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[c35] 35. The method of claim 32 further comprising the following steps when the value of the first ratio is not greater than the predetermined value:
applying a third voltage to the upper layer interconnection line, the third voltage is a swing time-dependent DC ramping voltage;
measuring a third leakage current flowing through the

upper layer interconnection line;
calculating a third proportional value from the third voltage, the third leakage current, and the equation, the third proportional value corresponding to the third voltage;
calculating a second ratio of the third proportional value to the second proportional value; and
performing the comparing step to compare the value of the second ratio with the predetermined value.

[c36] 36. The method of claim 35 wherein the steps (a) to (e) are repeated when the value of the second ratio is not greater than the predetermined value.

[c37] 37. The method of claim 35 wherein the quality of the inter layer dielectric is degenerated to be not acceptable when the value of the second ratio is greater than the predetermined value.

[c38] 38. The method of claim 35 wherein the third proportional value is a β3 value corresponding to the third voltage and the β3 value is equal to

【{△ln[|the third leakage current|/(|the third voltage|-|a flatband voltage(V_{fb})|)^2]}÷{△[1÷(|the third voltage|-|the flatband voltage|)]}】

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[c39] 39. The method of claim 38 further comprising a step for plotting a β-V curve of each β value respectively corresponding to the first voltage, the second voltage and the third voltage versus the first voltage, the second voltage and the third voltage, a reference β-V curve for the unstress-induced inter layer dielectric is compared with the β-V curve to monitor the quality of the inter layer dielectric.

[c40] 40. The method of claim 39 wherein the β-V curve comprises at least two regions.

[c41] 41. The method of claim 39 wherein the absolute value of the β value increases to represent the stress-induced leakage current (SILC) resulting in the increase of each leakage current flowing through the upper layer interconnection line.

[c42] 42. The method of claim 32 further comprising a step for plotting a β-V curve of each β value versus each voltage, a reference β-V curve for the unstress-induced inter layer dielectric in the interconnection structure is compared with the β-V curve to monitor the quality of the interconnection structure.